DAMASCUS NATURAL FEATURES INVENTORY

NATURAL HAZARDS REPORT

Prepared for:

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Landslide and Seismic Hazard Assessment

TROUT MOUNTAIN FORESTRY WITH MIKE ANDREWS
Wildfire and Winthrow Hazard Assessment

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Damascus Natural Features Inventory
Natural Hazards Report

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Introduction

The City of Damascus retained a consultant team led by Winterbrook Planning to conduct an inventory of natural hazards within the city limits. The inventory addresses the geologic and seismic hazards, wildfire hazards, windthrow hazards and flood hazards. Natural hazards are addressed by Statewide Planning Goal 7. The inventory provides an important base of information and strategy recommendations on natural hazards that will inform subsequent steps in the Comprehensive Planning process.

This report is a companion to the Damascus Goal 5 Natural Resources Inventory Report, submitted under separated cover. The report begins with a brief review of study area characteristics and public involvement efforts. Each hazard is then addressed individually, beginning with a brief overview and review of inventory methods, a summary of inventory results, and a review of recommendations on how to mitigate the risks posed by natural hazards. The Natural Hazard Map (Figure 1) illustrates the combination of natural hazards in Damascus that can be readily mapped. The report concludes with a list of references for each subject area.

Public involvement and outreach for the Damascus Natural Feature Inventory project began in the fall, 2006 and continued through June, 2007. The process included extensive landowner notices (to more than 1,400 landowners), two series of public meetings, published notices and articles in the *The Observer*, on the City's web site, and at City Hall. A Natural Features Topic Specific Team was established to review the inventory work and make recommendations to the City Council. The committee was composed of a representative group of citizens from the Damascus community. A more detailed review of the public involvement efforts is provided in the Goal 5 Natural Resources Report, the companion piece to this report.

The Goal 7 inventory and associated map provide the basis for subsequent steps in the Comprehensive Planning process. As part of that process, the consequences of alternative conservation and development strategies will be weighed, through a public process, and an appropriate Goal 7 hazard program will be developed.

Summary of Findings

The following is a brief synopsis of key findings and recommendations of the Damascus Natural Hazard Inventory. Methods for collecting information for these reports included analyzing existing maps and other data from Clackamas County, Metro, Department of Geology and Mineral Industries, Federal Emergency Management Agency, and other public agencies as well as onsite fieldwork where local property owners granted access. The inventory was completed to address State Land Use Goal 7 (Natural Hazards).

Slopes

Based on the field inventory, slopes steeper than 25 percent are assumed to be unstable or potentially unstable. Total steep slope area is 1,030 acres or roughly 10 percent of land within Damascus.

Recommendation:

- Prior to development, slopes steeper than 25 percent should be evaluated by a Certified Engineering Geologist (C.E.G). If the slope is found to be unstable, analysis and mitigation measures should be taken.

Landslides

Hillsides show evidence of previous landsliding. Total landslide topography area is 1,489 acres or roughly 14 percent of land within Damascus. Area of rapidly moving landslide is 156 acres or 1.5 percent of land within Damascus.

Recommendation:

- Prior to development within 100 ft of mapped landslide topography or on landslide areas, a geologic assessment should be prepared by a C.E.G. that investigates the limits and stability of the slide mass, and the mechanics of slide movement locally.

Drainage

Based on available data and field observation, high groundwater is expected to be present throughout the wet season.

Recommendations:

- Surface water should be controlled such that it does not impact adjacent property by increasing flow, concentrating flow, or stimulating erosion.
- Prior to new development, a storm drainage plan should be submitted and approved by the City.
- Developments should incorporate basement and foundation drainage to control groundwater.

Fills

Significant fills and those obscured by age and previous development are present throughout Damascus.

Recommendation:

- Geologic and geotechnical investigations should address the presence or absence of man-made fills as part of the reporting process.

Wildfire

Wildfire is influenced by four major factors: fuels, weather, topography and ignition. Total area of wildfire hazard is 175 acres or 1.6 percent of land area within Damascus.

Recommendations:

- Adapt the Clackamas County Community Wildfire Protection Plant to local conditions and encourage residents to follow the recommendations of local fire agencies experienced in protecting homes from wildfires.
- Consider an ordinance requiring lots with grass to be mowed by August 1.

Windthrow

Windthrow occurs when trees are snapped or uprooted by high winds. The primary factors contributing to windthrow likelihood are root and stem diseases, saturated soils for prolonged periods, land clearing, and landscape position.

Recommendations:

- Consider development of a tree ordinance that will reduce the risk of windthrow.
- Develop a program to encourage or even require “clumped” rather than “dispersed” retention of trees during subdivision and housing development to reduce the risk of windthrow.

Floodplains

Floodplain hazards in the study are documents by FEMA. Total floodplain acreage is 140 acres or 1.3 percent of land area within Damascus.

Recommendations:

- Consider designation of areas such as parts of Sunshine Creek as flood erosion hazard areas pending specific project-related hydraulic analysis.
- Prior to large scale developments areas of steeper stream gradient should receive reach specific hydraulic/ hydrologic analysis

Study Area Overview and Geology

The City of Damascus is located in northern Clackamas County, south of Gresham and the Pleasant Valley area, and east of Happy Valley. The City includes the communities of Carver (on the Clackamas River) and Damascus. The City borders the Clackamas River to the south and Multnomah County to the north (see Figure 1). The study area is generally defined as the city limits, with a total size of 10,333 acres. The City/study area extends outside the Urban Growth Boundary to the southeast, near the junction of Oregon 224 and 232nd Avenue.

In general, the Damascus area is characterized by a series of conical buttes in the western and northwestern portion of the City (East Buttes/Boring Lava Domes), separated by erosional stream valleys. The eastern part of the City is more characterized by rolling hills and shallower stream and ancient floodplain valleys. The southern part of the City borders the Clackamas River valley and is characterized by steep erosional valley margins, stream canyons, and portions of the Clackamas River floodplain

The buttes were formed by a series of volcanic eruptive centers during the Late Pliocene to Pleistocene. Prior to the eruptions, the area was characterized by relatively flat, rolling hills and plains topography formed by the deposition of the Sandy River Mudstone and Troutdale Formations. The eruptions spread lava flows, ash fall, and mud flows over the region, filling stream valleys and altering the landscape to a semblance of what it is today. The present ground surface surrounding the buttes and in the Sunshine Valley region in the eastern part of the City are covered by a formation referred to as Pliocene-Pleistocene Gravels which are the erosional remnants of erupted mudflow deposits, both within the Damascus area, and from the east. and southeast toward the Cascade Range.

Since that time, the area has been more subject to erosion than depositional (accumulation of sediments) or tectonic (large scale crust movement) activity. The exception would be the Aeolian Silt deposits of the Portland Hills Silt that still cover the surface of the buttes in the northwest corner of the City.

The ground surface along the Clackamas River floodplain is characterized by steep, actively eroding slopes within the Troutdale and Sandy River Mudstone Formations. Many areas along the Clackamas River have exposed sandstone beds, such as those near the Carver Bridge, which represent remnants of erosion-resistant portions of the Troutdale Formation.

In general, Schlicker and Finlayson (1979) and Trimble (1963) describe the geology of the area and list seven major geologic units within the Damascus city limits. A brief description of the units follows:

- **Alluvium.** Unconsolidated sand, gravel, and cobbles within stream channels and on adjacent flood plains; sandy silt up to 10 feet thick overlies gravel on flood plains.

- **Pleistocene Terrace Deposits.** Unconsolidated cobble and boulder gravel and silty mudflow deposits up to 200 feet thick along the Clackamas River, Richardson Creek, and Pleasant Valley in this area.
- **Aeolian Silt.** This formation is a wind-blown (loessal) silt deposit that caps some of the buttes in the northwestern portion of the City. The silt in this area is thought to be a maximum of 55 feet thick and to occur generally above elevation 250. Within the City of Damascus the silt appears to be present above about elevation 400 feet Mean Sea Level (MSL).
- **Pliocene-Pleistocene Gravels.** This formation is composed of gravel and mudflows with weak cementation, poor sorting, and rounded cobble and boulder-sized material. Many of the deposits were derived from pyroclastic (mixture of rock and ash explosively ejected from a volcanic vent) mudflows and are weathered and decomposed to a reddish-brown clayey soil. The deposits are as much as 400 feet thick and are poorly drained. They are nearly impermeable in places, and because of the poor quality of the rock and large number of fines, they are generally not suitable for aggregate production (Gray, 1978). In the eastern portion of the City the gravels were derived from similar volcanic events eastward toward the foothills of the Cascade Range.
- **Troutdale Formation.** This formation consists of Pliocene sandstones and conglomerate in a partially cemented state. The identifying marker is quartzite which makes up about 30 percent of the grains. The matrix can be composed of a volcanic glass that when deeply weathered can form a high shrink-swell clay.
- **Sandy River Mudstone.** This formation, in keeping with its name, is composed primarily of a fresh water mudstone with some siltstone and sandstone. The unit has a maximum thickness of about 725 feet. The clayey materials are very low strength and are prone to earth flows and slump failures of overlying, more intact rock formations.
- **Boring Lavas.** This is a Pliocene-Pleistocene, light gray olivine basalt with flow structures and some pyroclastic (explosive) materials near vents. Where underlain by weak soil and rock materials these materials are prone to deep bedrock sliding. The Boring Lavas appear to cover about half of the ground surface in the Damascus area.

Geologic and Seismic Hazards

Hazard Mapping

The mapping program consisted of a library research of existing maps and publications available for review, and identifying areas that needed field observation to verify or refute anticipated conditions. The next task involved a field overview of the mapping area to identify features on existing hazard maps and additional ones that show up on the Light Detection and Ranging (LIDAR) survey. The project team then prepared preliminary hazard maps and identifying areas that needed closer inspection. The last phase of field mapping was spent visiting areas that the project team felt deserved closer scrutiny in order to refine the preliminary maps. Based upon the literature search and field mapping, the team prepared the geologic hazard maps and this report for inclusion in the overall Goal 5 and Goal 7 Resource Inventory.

Review of Existing Data and Hazard Maps

Prior to starting the field reconnaissance program, the project team reviewed existing geologic and geotechnical publications in the area, many of which are listed at the end of this report in the References section. The project team reviewed USGS Maps of the area, aerial photography, LIDAR survey information and maps, and visited with Clackamas County Building and Planning personnel to research past geotechnical and geologic reports in the Damascus area. However, very little geotechnical and geologic information was available. The project team also talked to the City of Damascus but due to the very short duration since the formation of the City, no records were yet available.

In 1979, the Department of Geology and Mineral Industries (DOGAMI) prepared a series of Geology and Geologic Hazard maps of the northwestern portion of Clackamas County, including the current City of Damascus boundaries. The hazards mapped by DOGAMI included slope steepness, mass movement (landslides, landslide topography, debris flows), soil hazards (organic, high shrink-swell, high water table), flooding, and stream bank erosion. Since that time, many of the Goal 7 elements incorporated into the 1979 study have been updated by government agencies and include:

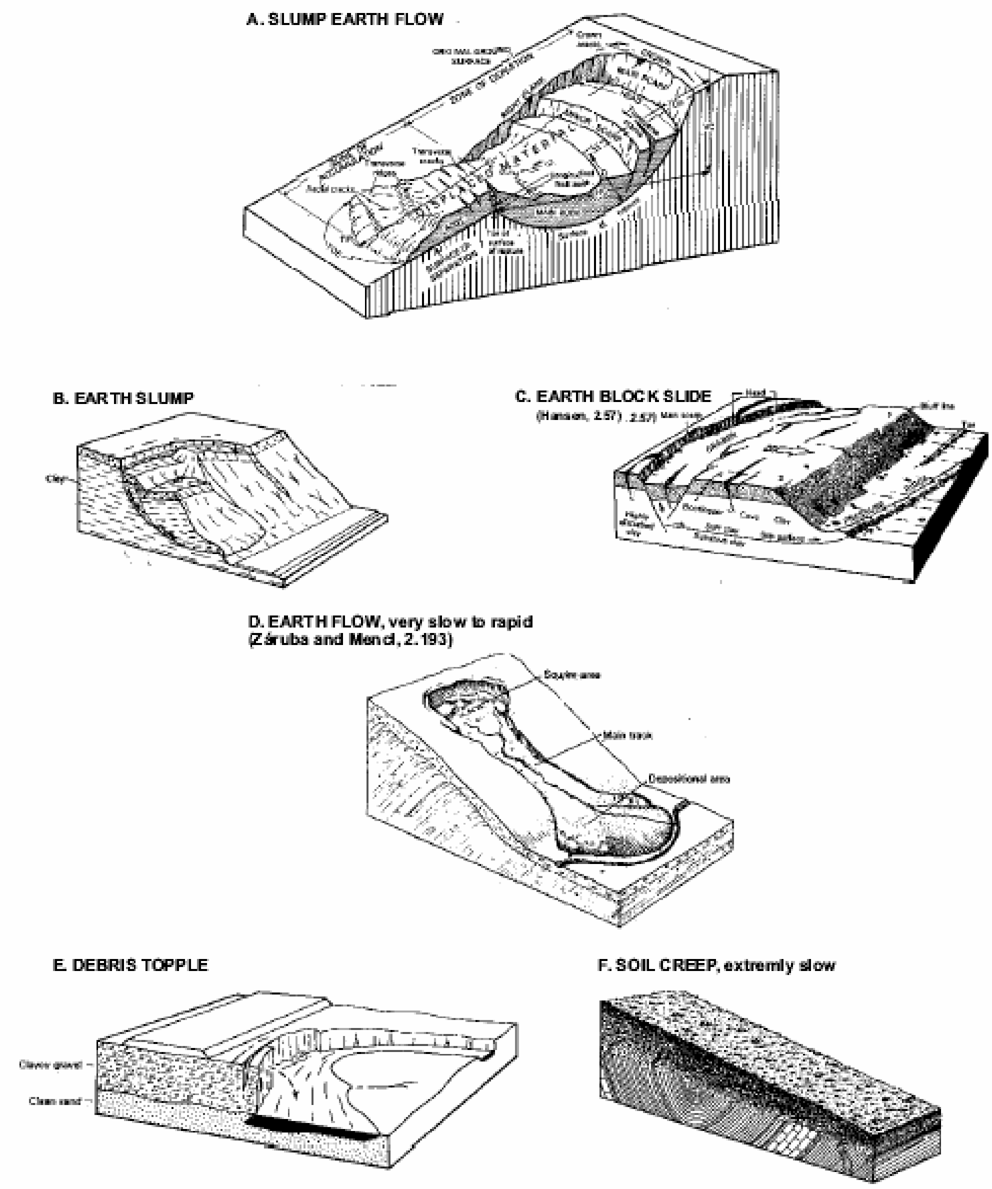
- Clackamas County Soil Survey (NRCS 1985 and current data available on-line only) that covers hydric soils, high groundwater, and shrink-swell potential of soils,
- Earthquake hazards (DOGAMI 1996, 1997, 2003), and
- Flood Insurance Rate Mapping (FIRM) studies (FEMA 1987, 2000, and 2006).

The Goal 7 Geologic Hazard study by Ash Creek Associates, Inc. has focused primarily on slope and landslide hazards.

Field Methodology

The field-mapping program consisted of initially visiting areas noted on previous Hazard Maps as Landslide Topography or Local Slump and earthflow, and apparent anomalies detected during this study using the LIDAR survey data, to verify the existence or absence of geologic hazards. Subsequent field mapping was used to refine the observations and more closely delineate the hazard areas. Figure 2 (derived from

Figure 2. Examples of Slope Failure.



Examples of Slope Failure
Goal 7 Hazard Study
City of Damascus
Damascus, Oregon

Ash Creek Associates, Inc.	Project Number	1303-00	Figure
	May 2007		2

Derived from: Figure 2.1 Transportation Research Board Special Report 176.

Schuster and Krizek,1978; and Turner and Schuster, 1996) provides examples of slope movements that might be found in the study area. In subsequent discussions, the project team may refer to particular features by Figure 2A, 2B, etc. While in the field the project team's observations included, but were not limited to:

- "Pistol-butted" evergreen (fir, cedar, etc.) trees, indicative of ground movement and subsequent attempts by the trees to correct themselves to a normal vertical growth. Only one or two deformed trees in a grove or forest would not be indicative of ground movement; their growth patterns could have been altered by ice loading, wind, or animal activity during early stages of development.

  Deciduous trees are not normally good indicators of movement and generally should not be solely relied upon to evaluate ground movement.

- Clumps of evergreen trees all leaning upslope (possibly indicating a rotational slump), leaning downslope (possibly indicating shallow movements pushing trees over while the roots attempt to hold them in place), or leaning and tilting in all directions (possibly indicative of translational movement disrupting the ground in all directions).

Older trees undergoing recent movement

- "Hummocky" topography consists of a rolling or lumpy appearing ground surface on relatively gentle slopes that generally results from debris flow or massive landsliding "run-out". Hummocky ground in and of itself is a clue, but not necessarily a result of landsliding. Surface topography can be controlled by geologic conditions beneath the surface in the form of undulatory lava flows, flood scouring, or man-made cut and fill areas.
- Sharp breaks in slope can be uppermost scarps of over steepened ground formed when a block of soil breaks loose and slumps downward (Figure 2A, 2B, 2C, 2D). The scarps are generally parallel to the contours, are usually arc-shaped, and are higher near the center of the arc and feathering out toward the sides.
- Cracks and bulges running downslope (perpendicular to the contours) can be shear zones at the slide margins (Figure 2A, 2B, 2C). Often surface water encounters "sag ponds" or flattened slope areas, and flows parallel to the scarp, turning downslope and following the shear zone (Figures 2A, 2B).
- "Teardrop" or "spoon" shaped hollows that narrow to a stream channel downslope and may or may not have a fan of material below the channel (Figure

2D). These features are commonly referred to as “blowouts”, earth flows, or debris flows.

- Closed depressions or grabens are hillside features that have interrupted normal drainage patterns (Figures 2A, 2C) and may or may not have visible outlets. If they contain water they may be referred to as sag ponds. These features can form when the scarp area of a rotational slide or slump tilts back into the hillside and cuts off flow.
- In areas of aggressive stream erosion the banks may be undercut causing the soil or rock to fail in blocks, or topple into the stream leaving a vertical or near-vertical slope behind (Figure 2E). The most visible examples of this condition occurs along the Clackamas River, primarily along the outside bend of active channels where the soil or rock does not have the opportunity to reach a relatively stable angle of repose before being undercut again. This particular form of erosion occurs along the north bank of the Clackamas River floodplain near the Baker Bridge in Carver. Toppling failures may occur on small streams or tributaries at a scale too small to map or observe.
- Pavement and curb cracks, fence misalignment, and other surface feature indicators can reflect ground movement from soil creep (Figure 2F). In forested areas, very slow and minor movements can be totally obliterated by topsoil, sod, brush, etc., whereas rigid structures such as curbs, pavement, retaining walls, etc., or those in visual alignment, can reflect very small movements (such as the undulating roadbed pictured here).


Soil creep: undulating pavement and curbs

- Springs and seeps. If springs and seeps are noted issuing from the face, or base, of a slope they can be indicative of a landslide mass covering a channel or a debris flow resting at the base of a slope. The slide mass remains saturated from infiltration into the top of the slide, or from the slide mass cutting below the groundwater surface. Rather than concentrated flow from a defined channel the occurrence of water may be widespread as a spring line or seepage zone with no defined source.

LIDAR Survey

LIDAR mapping has been around since the 1960s, but has only been in use for terrain modeling for about 10 years. Clackamas County had a LIDAR survey performed as part of an overall Portland Metropolitan mapping project. The City of Damascus was included in the survey and that data was the primary non-field mapping tool used in this study. Previous hazard mapping used United States Geologic Survey (USGS) maps with 10 foot contour intervals based upon aerial photography. The LIDAR survey allowed us to refine many of the boundaries of previous hazard maps and to identify additional hazard areas.

LIDAR is an active sensor, similar to radar that transmits laser pulses to a target and records the time it takes for the pulse to return to the sensor receiver. This technology is currently being used for high-resolution topographic mapping by mounting a LIDAR sensor, integrated with Global Positioning System (GPS) and inertial measurement unit (IMU) technology, to the bottom of aircraft and measuring the pulse return rate to determine surface elevations.

Recent studies indicate that LIDAR can increase the number of identified landslides by 2,000 percent over conventional USGS 10-meter elevation models, while decreasing the minimum size of detected slides from almost 35,000 m^2 to less than 30 m^2. In the fall of 2006, DOGAMI published its bulletin *Cascadia* (Vol. 4, No. 2), which serves as an excellent guide to how LIDAR is used, the limitations of low-resolution contour information, and the status of ongoing LIDAR projects in Oregon.

Map Presentation

On the final Hazard Maps, the project team combined historical (Schlicker and Finlayson) DOGAMI maps of Clackamas County Landslides and Landslide Topography with those identified in the current study. For ease of presentation, the team's final maps combine past and present mapping into one consistent product with the text of this Hazard Report and map key explaining that the Landslide Topography on the City of Damascus maps is a combination of the two studies. The Clackamas County DOGAMI study (Schlicker and Finlayson), the on line NRCS Soil studies, and FEMA (FIRM) flood maps are available as independent documents.

Hazards

Slope hazards and landslide topography have been the primary targets mapped as part of the Goal 7 resource study for the City of Damascus. Although not necessarily associated with slopes the project team has also included discussions on moisture-sensitive soils (high shrink-swell potential), high groundwater, and man-made fills. The following sections provide a brief description of the hazards associated with this study.

Steep Slopes

The slope hazard areas used for this study generally place slopes in two categories of steepness: 0 to 25 percent and greater than 25 percent slopes. In the project team's opinion, these categories are appropriate for the geologic conditions within the Damascus area. The Schlicker and Finlayson Hazard Maps (Bulletin 99) show five slope categories but their study covered a very large area with greater varieties of geologic conditions. Slopes greater than 25 percent are shown on the Natural Hazard Map (Figure 1). The total area encompassed by steep slopes in Damascus is 1,030 acres.

Most of the existing steep slopes in the Damascus area have geologic conditions consistent with widespread landslide topography, and since no site-specific subsurface information is available to contradict the assumptions, the project team has assumed that slopes steeper than 25 percent are potentially unstable and will require independent evaluation prior to development. Certainly, there are isolated areas of steep slopes that are not potential landslide hazards, such as the basaltic cliff face between SE Winston and SE Heuke Road.

Soil Creep

Soil creep occurs primarily on natural slopes steeper than approximately 25 percent; on slopes over-steepened by cutting or filling, adjacent to drainages, and near areas of active erosion. Soil creep occurs when soil particles undergo short scale movements from cyclic wetting and drying, or freezing and thawing. On a near-microscopic scale, if a soil particle is exposed to swelling (from moisture adsorption) or freezing it will move upward perpendicular to the slope face. When the particle is dried or thaws, it will move vertically downward resulting in a net movement down slope.

Movements may be on the order of a few millimeters or centimeters per year, and may not be detectible on an annual basis. Soil creep can cause shallow-rooted evergreen trees to tilt downslope, and as they right themselves they may develop pistol-butted trunks similar to areas of slow moving landslides. However, over a period of 10 or 50 years an object resting on the ground surface may move as much as 12 to 60 inches Soil creep is typically confined to the upper two to three feet of soil and can be

Trees as indicators of slope movement

controlled by maintaining a vegetative cover of deep rooting material, flattening slopes, constructing retaining walls, or embedding foundations. The Hazard Maps do not specifically identify soil creep, but they assume that it occurs on slopes steeper than 25 percent such as those along the north side of Borges Road east of Tillstrom and along the stream margins adjacent to the buttes.

Landslides - General

The landslide topography depicted in this report includes those areas shown on the existing Clackamas County hazard maps (Schlicker and Finlayson DOGAMI Bulletin 99) and those derived from this investigation. Approximately 1,489 acres of land in Damascus is mapped as landslide topography on the Natural Hazard Map (Figure 1). As noted above, all slopes steeper than 25 percent should be considered as potentially unstable and landslide-prone. In the case of many ancient landslides, the movement has resulted in slopes flatter than 25 percent (such as in the Kingswood area and north of Rock Creek east of Foster) surrounded by scarp areas steeper than 25 percent.

As discussed in a previous section, the underlying bedrock in this area is several millions of years old and has undergone deep chemical and mechanical weathering. The topography in the Damascus area and the present day slope configurations has been formed by hundreds of thousands (and in isolated cases, millions) of years of soil and rock movement generated by earthquakes, volcanoes, floods, stream erosion, and landslides (Schlicker and Finlayson, 1979; Trimble, 1963; Wells and Snavely, 1983). This being the case, the soil and rock on the existing slopes are assumed to be in a state of near-equilibrium under historic conditions. Depending upon the type of the rock and soil, the slopes may be subject to renewed movement if disturbed by earthquakes, undercutting, re-routing of stream or drainage courses, raising groundwater levels, removing vegetation, etc.

In addition, non-engineered fills placed on slopes can create a soil or rock overload triggering landslides, and fills placed over eroding streams or shallow, sloping bedrock can move down slope. A current example of this can be seen on Eckert Road as it crosses the stream valley south of Highway 212.

Rapidly Moving Landslides

Mudflows or debris flows are another type of landslide, commonly termed Rapidly Moving Landslides (RML), which can occur naturally or can be man-caused. The total area of potential RML hazards in Damascus is 156 acres. The Oregon Department of Land Conservation and Development (DLCD), Oregon Forestry Department (OFD), Earth Systems Institute, and DOGAMI collaborated on a paper (DOGAMI Interpretive Map Series IMS-22) to map RML throughout the state of Oregon. Although the information has not necessarily been field verified, the hazard maps include zones within the Damascus city limits that were mapped as having the potential for RML. Where the project team was able to verify landslide topography conditions, and the RMLs were within the landslide topography zones, the team incorporated them into the zones. Two notable areas where this occurred are the large slide area east of the Carver Bridge and the area of Royer Road above Highway 224.

Soils with High Shrink-Swell Potential

These soils can generally be derived from two sources within the Damascus area:

- Residual soils formed from in-place weathering of the Sandy River Mudstone, or
- Flood plain sediments derived from the Sandy River Mudstone or eroded ash deposits derived from weathering of Boring Lava materials.

The mapped exposures of these soils (Schlicker and Finlayson) are generally concentrated in drainages immediately east of the Damascus city center (Boring Lava derived), and in known landslide areas along the Clackamas River (Sandy River Mudstone derived).

Fills

Man-made fills are an integral part of any developed area, and if properly constructed they can simulate strength properties of the native soils. The modern-day building codes regulate the placement of fill soils with controls on soil types, moisture content, and compaction effort.

The fills most likely to cause problems are those that were placed prior to building code implementation or enforcement (which generally began in 1974). Many of the landslide areas mapped during the 1996 floods occurred within filled areas on public roadways, mostly on Oregon Highway 212 and 224, and are indicated on the Goal 7 Hazard Map as “Landslide Locations – DOGAMI.” Fills that have failed more recently can be observed on SE Eckert Lane, Immediately south of Highway 212 and on Borges Road along the drainage west of SE 222nd Drive. Fills that have settled and caused bumpy, wavy, or cracked pavements (but are not considered landslides) can be observed on virtually any secondary road that traverses a steep hillside or crosses a drainage. Because historically non-engineered fills are widespread and are generally obscured by recent vegetation, it is not possible to map them all nor is it possible to discern whether they meet modern engineering requirements. For these reasons it should be up to the permit applicant and their consultants to determine whether any pre-existing fills would have a detrimental effect on their development.

High Groundwater

High groundwater can result in softening of near-surface soils, flooding, landsliding, and spring activity. High groundwater areas were mapped by DOGAMI on Bulletin 99 using NRCS and existing geologic mapping information. In general the high groundwater conditions are defined as water levels being within at least 1.5 feet of the ground surface during the wet season. The conditions are a result of poorly drained or clayey soils, porous soils resting on a clay layer that retards infiltration, or relatively thin soils developed on gently sloping bedrock. The high groundwater areas generally include the entire City of Damascus, but some of the exceptions are:

- A few isolated slopes along the Clackamas River and other incised drainages where the slopes are extremely steep and the soils very thin;
- A few acres of bluff top areas where Boring Lava is near the ground surface, both above the Clackamas River and the top of the butte along Debora Street; and
- Some of the gravelly terraces along the Clackamas River.

High groundwater can cause excavation and caving problems in utility trenches and construction cuts; cause basement walls and floors to crack and leak; cause underground storage tanks and swimming pools to rise; and prevent infiltration of septic effluent.

The project team's general recommendation is to assume that high groundwater will be present throughout Damascus during the wet season, and provisions should be made for controlling surface and subsurface water in all new construction.

Regional Seismicity

The Portland Metropolitan area, including the City of Damascus, is widely acknowledged to be in an area of impending seismic hazards. The most likely hazards are liquefaction, ground subsidence, ground shaking, and earthquake-induced landslides. DOGAMI has produced earthquake hazard maps (Interpretive Map Series IMS-1 Relative Earthquake Hazard Map of the Portland Metro Region) that include Clackamas County and the City of Damascus. A comprehensive seismic hazard study is beyond the scope of the current project. However, some elements of earthquake hazards are related to the current study, so the project team will briefly relate the known conditions to potential seismic hazards.

Seismic Hazards

The December 2004 subduction zone earthquake and tsunami inundation in southeast Asia is evidence of the destructive nature and dangers associated with subduction zone earthquakes. The states of Oregon and Washington have a similar geologic setting offshore within the Cascadia Subduction Zone (CSZ). In addition to tsunami damage, the shaking action from large earthquakes can cause terrestrial landslides, submarine landslides, and seiches (Seiche is the back and forth sloshing of waves in bays or closed basins, and on occasion can be as destructive as a tsunami). The City of Damascus would only be concerned with potential damage from ground shaking, landsliding, and liquefaction

Liquefaction is the settlement or lateral spreading of unconsolidated, cohesionless sediments by ground shaking in an area of saturation. This model generally fits relatively flat-lying areas of cohesionless soils and granular fills under saturated conditions such as those noted previously in the Rock Creek watershed..

Ground subsidence is another hazard related to CSZ earthquakes, but is mostly an issue along the Oregon coastline. Ground subsidence can also occur as a result of liquefaction of soils on moderate slopes or adjacent to stream banks.

Ground shaking can cause building collapse and liquefaction of granular soils as described above. The primary danger is usually from falling debris.

Landslides can be generated by earthquake induced ground shaking, especially on steep slopes combined with saturated soils. Non-engineered fills on steep slopes are highly vulnerable to earthquake-induced landslides.

Regionwide Events

Very large earthquakes can cause damage many miles away from the epicenter, and although Damascus is not seismically active, it is susceptible to damage from distant earthquakes. The seismicity in the Portland Metropolitan area, and hence the potential for ground shaking, is controlled by three separate fault mechanisms. These include the CSZ, the mid-depth intraplate zone, and the relatively shallow crustal zone. Descriptions of these potential earthquake sources are presented below.

The CSZ is located offshore and extends from Northern California to British Columbia. Within this zone, the oceanic Juan De Fuca Plate is being subducted beneath the continental North American Plate to the east. The interface between these two plates is located at a depth of approximately 15 to 20 kilometers (km). The seismicity of the CSZ is subject to several uncertainties, including the maximum earthquake moment magnitude (Mw) and the recurrence intervals associated with various Mw earthquakes. (Moment magnitude is used by seismologists to measure larger earthquakes and is based on fault displacement and area of fault rupture, while for smaller earthquakes, the moment magnitude is approximately equal to the familiar Richter Scale Magnitude.) Anecdotal evidence of previous CSZ earthquakes has been observed within coastal marshes along the Oregon coast, establishing the existence of these events. Sequences of interlayered peat and sands have been interpreted to be the result of large subduction zone earthquakes occurring at intervals on the order of 300 to 500 years, with the most recent event taking place approximately 300 years ago. A definitive study of Oregon seismic hazards completed by Geomatrix (1995) suggests that the maximum earthquake associated with the CSZ is Mw 8 to 9. This is based on an empirical expression relating Mw to the area of fault rupture derived from earthquakes that have occurred within subduction zones in other parts of the world. A Mw 9 earthquake would involve a rupture of the entire CSZ. As discussed by Geomatrix (1995), this has not occurred in other subduction zones that have exhibited much higher levels of historical seismicity than the CSZ and is considered unlikely. For the purpose of this study, an earthquake of Mw 8.5 was assumed to occur within the CSZ.

The intraplate zone encompasses the portion of the subducting Juan De Fuca Plate located at a depth of approximately 30 to 50 kilometers below western Oregon. Very low levels of seismicity have been observed within the intraplate zone in Oregon. However, much higher levels of seismicity within this zone have been recorded in Washington and California. Several reasons for this seismic difference were suggested in the Geomatrix (1995) study and include changes in the direction of subduction between Oregon and British Columbia as well as the effects of volcanic activity along the Cascade Range. Historical activity associated with the intraplate zone includes the 1949 Olympia Mw 7.1 and the 1965 Puget Sound Mw 6.5 earthquakes. Based on the data presented within the Geomatrix (1995) report, an earthquake of Mw 7.25 has been chosen to represent the seismic potential of the intraplate zone. Shaking in the Damascus area can be felt from these earthquakes but damage is expected to be slight.

The third source of seismicity that can result in ground shaking is near-surface crustal earthquakes (less than 30 kilometers in depth) occurring within the North American Plate. The historical seismicity of crustal earthquakes in western Oregon is higher than the seismicity associated with the CSZ and the intraplate zone. The 1962 Portland earthquake and the 1993 Scotts Mills (Mw 5.6) and Klamath Falls (Mw 6.0) earthquakes were crustal earthquakes. Only light damage was reported in the Portland area from these quakes, mostly from the 1962 event.

Earthquake Hazards

Compared to the Portland and western Washington County areas, according to Mabey (1996 and 1997), the Damascus area ranks relatively low in the earthquake hazard ratings, with no discernable movement on any of the nearby faults within the past 20,000 years. Ground response to earthquakes outside the city limits are discussed in a subsequent section of this report. In general the earthquake hazards are directly related to the underlying geology. If ground conditions are soft, loose or saturated, liquefaction or ground amplification can occur. If slopes are steep due to the relative consistency of the underlying bedrock, if the bedrock is soft and unstable, or if landsliding has occurred previously, landslides can be induced by ground shaking. The hazards rated by Mabey *et al.* (1997) include Liquefaction, Relative Amplification of Peak Ground Acceleration, and Relative Slope Instability. The categories were then combined and an overall rating map was produced. A generalized discussion of the categories of earthquake hazards is discussed below:

- Very few of the soils underlying Damascus would be classified as subject to liquefaction hazards. The exceptions would be the Rock Creek Watershed. With this being the case, the project team does not recommend a liquefaction study be required on all new construction. The DOGAMI IMS-1 publication (see Mabey *et al.* 1997) should be used as a guide in determining the relative potential for liquefaction in private developments. During the course of subsurface analysis, the liquefaction potential of the soils should be assessed by groundwater levels and soil grain size distribution. By doing so, the owners can judge whether their developments could be impacted by settlement-induced liquefaction. Critical facilities (hospitals, fire stations, etc.) are required by prevailing law to be evaluated for liquefaction, tsunami run-up, seiche, etc., so they are already covered.
- Soil and soft sedimentary rock at the ground surface can modify, or amplify, bedrock ground shaking caused by an earthquake. This modification can increase (or decrease) the strength, duration, or frequency of the shaking. The areas of Damascus susceptible to ground amplification are very closely related to those susceptible to liquefaction.

Earthquake-induced landslides occur on steep slopes or in areas of previous landsliding that are reactivated by the shaking. IMS-1 ranks these hazards in four categories with the lowest being in very flat or unusual locations and the highest being in areas of 45% or steeper slopes (24.2^{o}), or in areas of previous landsliding. The City of Damascus Slope Hazard rating of 25 percent or steeper being considered unstable generally coincides with the IMS-1 earthquake hazard rating between 1 and 2 or slopes on the order of 15^{o} or steeper.

Discussion and Recommendations

Throughout the Pacific Northwest and California a large number of state, county, and local level agencies have developed Natural Hazard Mitigation Plans to cope with natural disasters. The plans are designed to reduce risk from natural hazards through education, outreach programs that foster partnerships with regional, state and federal agencies; and implementation of preventive activities such as land use programs that restrict and control development in areas subject to damage from natural hazards. Within the immediate area, the State of Oregon Office of Emergency Management (OEM), the City of Salem, Oregon, and Washington County OEM have all developed Mitigation Plans that are generally available on the internet. As an example, we have listed the Uniform Resource Locator (URL) for Washington County Landslides in the References section of this report.

As noted previously, this study has been conducted to provide the City of Damascus with tools to aid in future planning and development. As the new development occurs, the materials contained in this report and on the accompanying maps are intended to trigger different levels of site evaluation, from visual geologic assessment to in-depth subsurface geotechnical explorations. Geologic assessments should be conducted by a State of Oregon Certified Engineering Geologist (C.E.G.) utilizing the *Guidelines for Preparing Engineering Geologic Reports in Oregon*, adopted by The Oregon State Board of Geologist Examiners (OSBGE). Geotechnical assessments should be conducted by a State of Oregon registered Professional Engineer (P.E.), with a specialty registration as a qualified Geotechnical Engineer (G.E.), and in cases where both engineering geology and geotechnical engineering are required, reports should contain the signatures and stamps of both.

Specific recommendations for each geologic hazard type are indicated with bullets.

Slopes

Slopes steeper than 25 percent are assumed to be unstable, or potentially unstable. Slope steepness alone should not preclude development but should be one of the items used to trigger closer planning and building scrutiny. Many of the slopes in this range of steepness are underlain by shallow bedrock and only the surface few feet of soil may actually be unstable. Based upon our reconnaissance-level mapping this could be the case in the area of SE 190th Ave and SE Tillstrom Road and other areas with the combination of steep slopes and basaltic bedrock,, but without landslide topography.

- Slopes steeper than 25 percent should be evaluated in detail by a C.E.G. through a geologic assessment prior to development. The preliminary evaluation can be visual depending upon access, the proposed type of construction, and potential effects on adjacent properties, in order to confirm the stability or instability of the slopes.
- Before a building permit or other land use approval is issued, the slope conditions should be verified by subsurface exploration. If the slopes are found to be unstable, analysis and mitigation measures should be made in conjunction with a G.E. using OSBGE guidelines and the Oregon State Board of Examiners for Engineering and Land Surveying (OSBEELS) standards of care for engineering practice.

Landslides and Landslide Topography

As the Damascus area continues to grow, because of the views and aesthetics the available land for development is often hillsides showing evidence of previous landsliding, or having surface characteristics of landslide topography. There are many areas mapped as having landslide topography or previous ground movement that are currently developed and have not had ground movement problems. One such area is along Kingswood Way in the northeastern part of the City. The hillsides were previously mapped by Schlicker and Finlayson (DOGAMI Bulletin 99), and currently by Ash Creek Associates, as having landslide topography and surface indicators of ground movement. This appears to be an area where ancient landslides have stabilized and not moved for decades. In areas such as this, development may be allowed, provided it is consistent with other policies adopted by the City. It should be kept in mind that potential effects of property adjacent to landslides can span the life of the structure or development, usually on the order of 50 years.

If movements are observed or measured in even small increments the long-term effects on development should be considered. For instance, in a heavily vegetated area movements of one or two centimeters per year can go undetected. However, if rigid structures such as pavements or retaining walls are constructed in the same area, over the period of 25 to 50 years displacements of 10 to 20 inches could occur.

Areas that are susceptible to severe erosion and ground movement should be considered very marginal for development. This includes the south-facing slopes above the Clackamas River east of Carver and in the area of Royer and Highway 224. Both of these areas have landslide topography, visible ground movement, and have been mapped as having RML susceptibility.

- All the areas mapped as landslides or as having landslide topography should be subject to the recommendations in this section.
- If development or construction is planned on or within 100 feet of mapped Landslide Topography, known or suspected landslides, or Debris Flow Hazard zones, the potential effects of the slide areas on the development should be made by a CEG through a geologic assessment. If the geologic assessment indicates that the land is developable and the potential hazards can be mitigated, the slide hazard area should be evaluated by subsurface exploration
- During any landslide investigation, the limits of the slide mass should be accurately measured and the stability of the slide mass and the mechanics of slide movement should be determined. This may (depending on opinion of a CEG) require installation of subsurface ground monitoring equipment (such as slope inclinometers) to determine whether deep-seated movements are occurring.
- All studies pertaining to slope stability should include an explanation of the methodology used and should provide recommendations for suitable setbacks, keeping in mind the anticipated life of the structure or development.
- If the known or suspected landslide area is to be built upon, or if the proposed development or structure is within the setback or buffer zone, an in-depth stabilization and construction plan should be developed by the CEG in conjunction with a GE using OSBGE standards for care for engineering practice.

Drainage

As noted previously, we have assumed that high groundwater will be present throughout Damascus during the wet season, and provisions should be made for controlling surface and subsurface water in all new construction. Anticipating that seasonal or permanent groundwater will be present in most of the Damascus area, all new construction incorporate basement and foundation drainage to control water and keep it from crawl space, under-slab, and below-grade areas. Ground water control can range from perforated PVC pipe for foundation drains to engineered retaining wall drainage systems. The following recommendations are appropriate:

- Surface water flowing from an existing property or new development should be controlled such that it does not negatively impact adjacent public or private property by increasing flow, concentrating flow, or stimulating erosion that was not present beforehand.
- New developments should submit a storm drainage plan at the time of application. The City of Damascus personnel should judge the adequacy of the plan based on the size and type of development and specific site conditions. The City may require an engineered Storm Drainage Plan if site conditions warrant..
- All new developments should incorporate basement and foundation drainage to control groundwater and keep it from crawl space, underslab, and below-grade areas.

Fills

Significant fills and those totally obscured by age and previous development are present throughout Damascus. A number of landslides were mapped within the Damascus city limits by DOGAMI and Portland State University (Burns, et al) after the 1996 flood and landslide events. Virtually all of the slides occurred in road fill areas with poor drainage (referred to on the Natural Hazards Inventory map as "Landslide Locations – DOGAMI").

- All geologic and geotechnical investigations should address the presence or absence of man-made fills as part of the reporting process.
- New development in filled areas should evaluate, using subsurface exploration, whether any deleterious materials (contaminated with wastes, structurally unsound, etc.) are present that may affect building foundations, utilities, or pavements in future developments.
- Initial evaluations of the suspected filled areas can be conducted by a CEG or GE. If conditions require recommendations for foundation construction outside those provided in the International Building Code (IBC), those recommendations should be made by a GE.

Wildfire Hazards

Methods

The project team reviewed existing aerial photography and GIS data and developed a GIS analysis of slope and aspect as risk factors for wildfire. Based on this analysis, the team's efforts were focused on those areas that potentially contained high fuel loads and/or significant risk to clusters of homes.

The project team then conducted limited ground-truthing of potential wildfire hazard areas within the City of Damascus and developed a map of potential wildfire hazards for digitizing. The field survey was aided by examination of aerial photographs, discussion with natural resource professionals, and the personal knowledge of co-author Mike Andrews, who is a long-time Damascus resident and wildland fire professional.

Findings

Wildfire is influenced by four major factors: fuels, weather, topography, and ignition. These components affect the likelihood that a fire will get established, the speed and direction in which a wildfire will burn, and the ability to control it.

- Fuels: Forest fuels consist mainly of living and dead vegetation. The amount, size, moisture content and continuity influence how fast and how far a fire will burn. In the wildland-urban interface, residential housing can also supply fuels that contribute to the spread of a wildlfire.

- Weather: Dry, hot and windy weather increases the likelihood of a major wildfire. These conditions make ignition easier, allow fuels to burn faster and increase fire intensity.

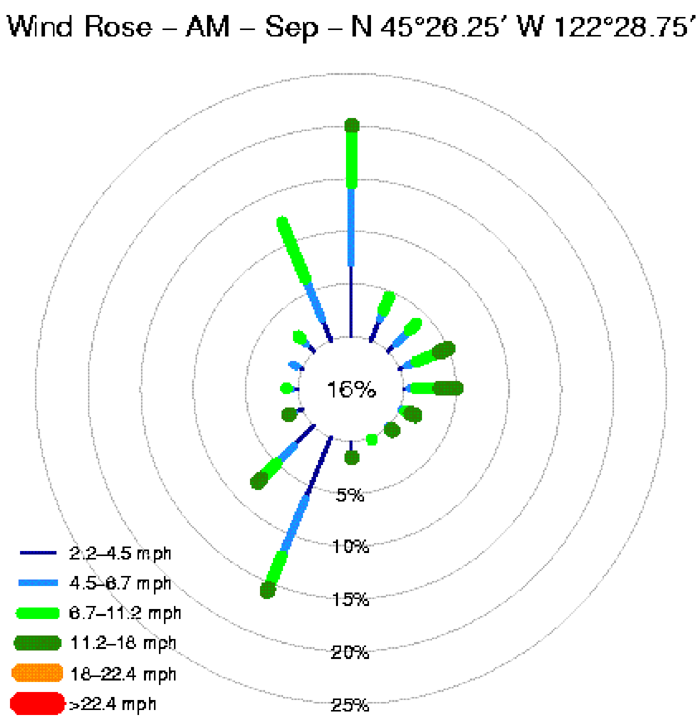
- Topography: Steepness and aspect of slope are the critical features of topography that affect fire behavior. As the steepness of slope increases, fire spreads more rapidly. Similarly, south and southwest aspects are driest and facilitate rapid fire spread.

- Ignition: Sources may include lightning strikes as well as anthropogenic sources.

Forest fuel types vary widely in the Damascus project area and reflect a long history of human activity. The term "fire hazard" refers to how flammable a given material is. Fire hazard is greatest where flammable fuels are continuous and heavy enough to carry fire through the landscape if not suppressed.

Dry, hot, windy weather conditions that are common in the project area in the late summer and early fall compound the existing fire hazard. During this time period, the hottest, driest winds come from the east. Other prevailing winds come from the north and southwest; however, these winds come from coastal areas and tend to have higher moisture content and therefore do not typically escalate fire conditions in the same way. These famous east winds come from high pressure cells in eastern Oregon that push hot dry air through the Gorge and into the greater Portland metropolitan area, including Damascus (Figure 3).

Figure 3. September Wind Rose for the Damascus area
Shows average wind speeds and directions during September. Prevailing winds are mainly from the N an SW, but E winds are a factor (Source: Ventilation Climate Information System, Joint Fire Science Program).



The Damascus area does include a number of volcanic buttes. Generally these topographic features do not present significant additional risk for wildfire because they do not tend to funnel winds in the way that steep canyons do. Further, the steep, south facing slopes that occur on these buttes are protected from the hot, dry East winds, thus mitigating the possible influence of these topographic features on wildfire risk.

General fuel types in the project area are: tall grass, brush, conifer forest, hardwood forest, mixed forest, and logging slash. Based on an analysis of aerial photography and limited field reconnaissance, the project team has identified a number of areas in Damascus that contain fuel types that could allow wildfire during certain climatic conditions. These areas are identified as wildfire hazards on the Natural Hazard Map (Figure 1) and together they cover approximately 175 acres of the City.

- Tall grass areas are fields that have not been mowed or grazed for one or more years. The resulting accumulated dead grass may remain a fire hazard for up to three years. Because the fuels are very fine and dry out quicker than larger fuel types, fires can occur in a wider time frame in grasses. Although late summer and early fall are typically the season when most fires occur, dry grasses can carry fire during extended dry periods in spring, early summer, and late fall.

- Brushy areas generally are clearings that historically were managed for various agricultural activities but have been abandoned and unmanaged for anywhere from five to twenty years. Fuels are characterized by accumulations of dead material (mostly leaves and limbs) from blackberries, hawthorn, scot's broom, sword fern, cascara, and grasses. Examples of these areas are abandoned pastures, tree nurseries, Christmas tree farms, and cane-berry fields. Because the brush is relatively short, there is high exposure to solar radiation all the way down to the ground and results in fuels that stay dry and flammable longer and that don't decompose as rapidly as shaded areas under a forest canopy. All of the areas identified on the fire hazard map have brush and/or brush-logging debris as the main component.

- Conifer forests are dominated by relatively even-aged second growth Douglas-fir with scattered western red cedar, western hemlock, and only minor amounts of hardwoods. Conifers have flammable oils in their needles which make them more of a fire hazard than hardwoods, both as live vegetation and as dead needles on the forest floor. Conifer forest canopies in the project area are usually dense, which results in sparse undergrowth. Canopy density also determines the amount of flammable dead limbs accumulating on the ground. Dense canopies result in light-starved lower limbs dying and dropping. Sparser canopies allow more sun to reach underneath and limit lower limb mortality. Because of the dense canopies in the project area there is a general absence of continuous ladder fuels. Ladder fuels are flammable materials that reach from the ground to the canopy. Continuous ladder fuels are necessary for large, catastrophic forest fires. Ladder fuels may exist around the outer edges of conifer forests where brush meets forest but usually not within the forest.

- Deciduous forests in the project area are characterized by a mix of even- and uneven-aged mostly non-flammable alder, maple, ash, cottonwood, and cherry.

These tree species generally maintain higher moisture contents in their leaves for longer periods as compared to evergreen species, and they generally lack the flammable compounds that are found in evergreens. Undergrowth is mostly non-flammable salmonberry, elderberry, and oceanspray, but may also contain pockets of Oregon grape and salal. Dead ground fuels are sparse and usually don't constitute a serious fire hazard. Flammable ladder fuels are generally not present.

- Most of the forests in the project area include a mix of conifer and deciduous species. There is a variety of ages and sizes of trees with understory species similar to pure deciduous forests. As a result, ladder fuels are generally not present except where conifer limbs reach close to the ground.

- Logging slash is debris from logging operations and it constitutes the most serious fire hazard in the project area especially in areas that have been clearcut. Clearcutting removes all the trees from a site and therefore adds heavy amounts of fuel to the ground. Within a few years of harvesting, the same flammable brush conditions that exist in other unmanaged areas also take over the clearcut adding even more fuel. The resulting extreme fuel accumulations make wildfires in these areas very difficult to control. Left untreated, logging slash can remain a fire hazard for 10-15 years.

The overall fire hazard in the Damascus project area is therefore relatively low based on the discontinuity of fuels and the general lack of extensive coniferous forests and associated high fuels concentrations. The areas with the highest hazard levels are mainly recently cleared areas where brush and slash pose short and medium term risks.

While fire hazard relates to the amount of flammable material, fire risk is the chance that a fire will actually occur. Fire risk in the project area is fairly high due to the large number of residents in a mostly rural setting. This presents a large number and variety of potential anthropogenic ignition sources. Wildfires in the project area are usually caused by activities common to rural settings: Debris burning, smoking, gas powered equipment (lawn mowers, chainsaws, heavy equipment, ATVs), fireworks, and children playing with fire.

County-wide, recent ten year averages show that lightning has caused about one to two fires per year on private land (Clackamas County 2005). In some years, lightning has ignited up to a dozen fires from one storm event in Clackamas County. These fires can create resource allocation problems as fire-fighting units are deployed to fight them.

The majority of fires in Clackamas County are caused by humans. The North Cascade District of Oregon Department of Forestry (ODF) lists debris burning as the number one cause of fires on forest lands in Clackamas County, causing more than 166 fires in the past ten years. The second leading cause of fires in the North Cascade District is recreation, which is less of a concern in the Damascus area as compared to the Mt. Hood National Forest. Miscellaneous causes include ignitions from electric fences, burning buildings and vehicles, spontaneous combustions and sparks from mufflers and converters (Clackamas County 2005).

Discussion and Recommendations

Because the forest fuels of concern are primarily on private land, the primary means of reducing the risk of wildfire are landowner educational programs and regulatory measures designed to provide incentives for fuels reduction projects. Recently, there has been a nationwide movement in federal and state agencies encouraging the development of Community Wildfire Protection Plans (CWPPs). Spurred by passage of the Healthy Forest Restoration Act (HFRA) in 2003, CWPPs are intended to provide a framework for identifying and prioritizing fuels reduction projects on both federal and non-federal land.

CWPPs typically are organized at the county level, are led by the local communities and receive support from federal agencies such as the USDA Forest Service; in Oregon, Josephine and Jackson Counties were the first to develop CWPPs. Located near the devastating Biscuit Fire of 2003, these communities had very tangible and immediate reasons for developing a comprehensive strategy to fuels reduction in the wildland urban interface. With growing concern about wildfire in northwestern Oregon, Clackamas County in 2005 developed and approved the Clackamas County Community Wildfire Protection Plan (Clackamas County 2005).

The Clackamas County Community Wildfire Protection Plan identifies 15 “communities at risk” within the county, one of which is the Boring Fire District. Within this district, Damascus has been identified as a strategic planning area, meaning it was identified as high hazard in community meetings and/or by fire district personnel.

Maps developed for the Clackamas County Community Wildfire Protection Plan indicate that the Damascus area rates moderate to high on fire hazard, based on fuels, topography, and climate; low on protection risk, based on proximity to fire-fighting resources and access; moderate on historic fire occurrence and ignition risk. The overall rating for the Damascus area generally ranges from low to moderate, which is consistent with the project team’s assessment.

The Oregon Forestland-Urban Fire Protection Act of 1997, better known as Senate Bill 360, was intended to reduce risk of wildfire in the wildland urban interface zones in the state, mainly by establishing standards for property owners so they can work to minimize fire hazards and risks. The Oregon Department of Forestry has only implemented this legislation in Jackson and Deschutes Counties. The law means that landowners that fail to adequately reduce fire hazards and risks on their properties may be liable for costs associated with fighting wildfire if it does occur. Although Clackamas County has not yet been selected for SB 360 implementation, the CWPP process is “laying the groundwork for implementation by coordinating agencies that have a vested interest in reducing wildfire hazards, implementing a wildfire prevention public outreach campaign, improving understanding of fire safe construction and practices in regulatory agencies, and promoting a more wildfire-based approach to managing the forests in Clackamas County.” (Clackamas County 2005). This type of regulatory approach would create a strong incentive for landowners to implement recommended fuels reduction practices on their properties in the Damascus area and throughout the County.

Recommendation #1: Expand on and refine the work conducted for the Clackamas County CWPP, tailoring its findings to local conditions. As development in the Damascus area continues, an increase in human ignitions is likely.

Recommendation #2: Encourage residents to follow the recommendations of local fire agencies experienced in protecting homes from wildfires. These pertain to creating a defensible space around buildings and to fire prevention measures.

Recommendation #3: Consider an ordinance requiring lots with grass to be mowed by August 1. This would ensure that the grass is mature and not likely to become a hazard again during fire season. The August 1 deadline will allow spring ground-nesting birds to successfully rear their young. The Oregon Department of Fish and Wildlife should be consulted on relevant bird species and timing.

Windthrow Hazards

Methods

Using an approach similar to the wildfire hazard assessment, the project team reviewed existing aerial photography and GIS data related to risk factors for windthrow. Limited ground-truthing of existing and potential windthrow hazard areas within the City of Damascus was then completed. Although topographic features do play a role in exacerbating windthrow risk, this phenomenon is much harder to predict or prevent than wildfire, and the project team determined that spatially explicit windthrow hazard ratings could not readily be developed for the project area.

Findings

Windthrow occurs when trees are snapped or uprooted by high winds. The primary factors contributing to windthrow likelihood are:

- Root and stem diseases, which structurally weaken trees
- Saturated soils during prolonged periods of rain

- Land clearing, which exposes trees previously sheltered from the wind to direct gusts
- Landscape position: ridge tops and slopes facing the prevailing winds, particularly during the wettest times of year, typically winter

Trees that have grown primarily in an opening generally have a well developed root system, which helps anchor them during high wind events. Trees that develop in dense stands, or groups, of other trees typically have small crowns and relatively small root systems. These trees are sheltered from high winds by surrounding trees and stem or root breakage is normally minimized. Forest fragmentation, which has occurred and will continue to occur in the Damascus area in the form of clearcutting, road and powerline clearing, and residential development, exposes interior-grown trees to direct wind and removes trees that formerly acted as supports and wind breaks. Windthrow can be expected in such situations, although predicting exact locations and timing of windthrow is difficult. Generally, root strength is proportional to size of crown. In areas of dense conifers, various root rotting pathogens can weaken and kills roots, removing most structural resistance to high winds.

Damage to Damascus home from windthrown timber. This occurred during the December 2006 windstorms.

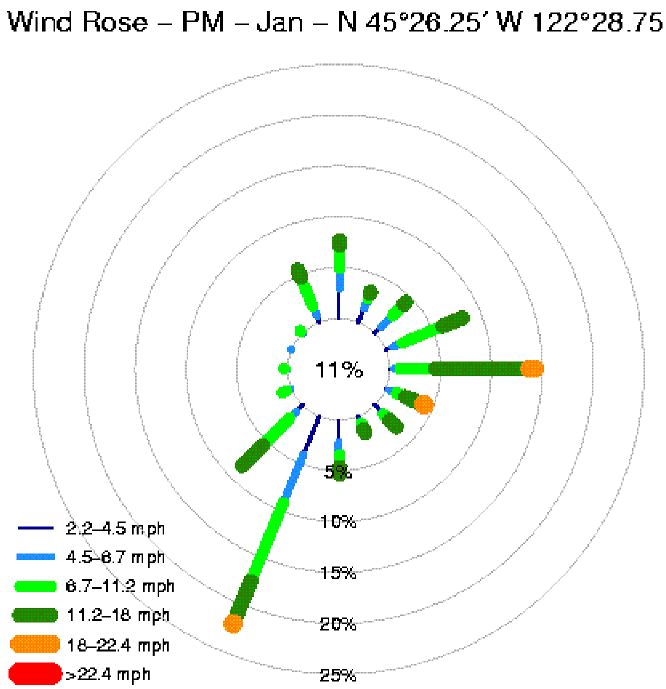
SW winds from December 2006 storm blew over a mature Douglas-fir on a ridgetop, which landed on this home in Damascus.

In the Damascus area, prevailing winds during winter include winds out of the southwest and east (Figure 4). Generally, exposed ridges are more susceptible to such winds, but there are so many variables that influence whether wind damage will actually occur, including tree health, tree density, soil conditions, and micro-wind patterns that it is very difficult to predict windthrow occurrence.

Windthrow is less likely in forest stands that have been thinned and managed over time to favor the healthiest, most wind-firm trees. Stands that are thinned or high-graded to remove the largest trees are typically very susceptible to windthrow.

In summary, within the project area there are no specific areas that can be singled out as having higher windthrow risk. New residential developments that attempt to retain mature trees should be encouraged because of the many benefits provided by mature shade trees; however, efforts should be made to encourage retention of the healthiest trees with the largest crowns to minimize the likelihood of windthrow.

Figure 4. January Wind Rose for the Damascus area
Shows average wind speeds and directions during January. Prevailing winds are mainly from the SW and E (Source: Ventilation Climate Information System, Joint Fire Science Program).



Discussion and Recommendations

Windthrow risk is increased when trees in a dense stand lose the support of some or all of their cohorts due to logging or other tree removal. Traditionally, large-scale housing developments that take place in forested areas have usually resulted in complete removal of the forest. Recently, the trend in development has included substantial efforts to preserve individual trees or groups of trees from the original forest to enhance the aesthetics and lived-in look of the development. This trend, while laudable for its attention to the values that mature trees can bring, has often resulted in trees blowing down.

One approach to this conundrum is to attempt "clumped" rather than "dispersed" retention (Maguire et al 2006). Dispersed retention involves retaining individual trees scattered throughout the project area, while clumped retention involves retaining one or more groups of trees. These clumps, if designed and executed properly, can offer a reduced risk of windthrow, as well as other benefits including increased aesthetic and habitat values.

Recommendation #1: Develop a tree ordinance to ensure that any tree cutting in residential areas does not result in an increased risk of windthrow. The ordinance could require that prior to cutting any mature trees, a city-endorsed arborist must verify that the cutting will not exacerbate windthrow hazards.

Recommendation #2: Develop a program to encourage or even require "clumped" rather than "dispersed" retention of trees during subdivision and housing development to reduce the risk of windthrow.

Flood Hazards

Methods

The evaluation of flood hazards for the Clackamas River floodplain was based on Federal Emergency Management Agency (FEMA) maps and data. Evaluation of flood hazards for the other landforms in the study area is based on general topography, soil/slope relationships, mapping of wetlands and hydric soils, and on the synoptic hydraulic/ hydrology evaluation for the area (Clackamas County Service District No. 1 Surface Water Management Plan). Reach specific hydraulic and flood forecasting analyses are not available in the study area.

Flooding of the Clackamas River has shifted the river's course. This bank has lost up to 100 feet in recent years.

Flood Hazard Assessment

Floodplain hazards in the study are well documented and delimited by FEMA for those lands in the Clackamas River corridor and for the lower Rock and Richardson Creek corridors. The lower (FEMA mapped) portions of Rock and Richardson Creeks are not within the Damascus city limits. FEMA 100-year floodplains within the city are shown on the Natural Hazard Map (Figure 1). The total mapped floodplain area is 140 acres.

Floodplain hazards along upper reaches of Rock and Richardson Creeks, along Sunshine and Noyer Creeks, and along smaller tributary basins on the northern project area periphery are not well defined, however, the *CCSD No.1 Surface Water Master Plan Hydrologic-Hydraulic Analysis* sheds considerable light on the general hydraulic and hydrologic problems for these drainages. In general, the hydraulic analysis documents that models are available that can adequately predict runoff and flow conditions during large storm events under different development scenarios. All of these streams except Sunshine Creek are moderate gradient streams with generally narrow floodplains.

However, each stream has reaches of lower gradient where local flood hazards may be more severe. Areas of specific development concern may require detailed modeling to identify specific flood heights and velocities during design storms.

In the absence of specific hydraulic modeling, existing natural features (such as embankment height, riparian vegetation, fluvial soil deposits, etc) may provide for preliminary estimation of potential flood threat areas. Lower Sunshine Creek and upper Noyer Creek have low to moderate gradients and may be at greater flooding risk. Detailed analyses of these basins are not available. Flooding hazards in the Sunshine Creek basin (Sunshine Valley) are expected to be primarily due to inundation of lower lying areas.

Some previous studies document that the East Butte/Boring Lava complex is likely not a significant recharge area both because of limited permeability of the boring lavas as well as the low permeability of the resultant weathered soil (Brody-Hein 2005); however, other studies (Ecotrust 2000) indicate that portions of this butte complex may provide critical recharge to aquifers feeding local streams. Soils in this landform are generally thin and slopes are steep to moderate. Stream flows in these areas are typically very flashy and respond rapidly to rainfall. Flood hazards in this landform group are limited in extent to the narrow drainage channels and can be readily observed by noting past scars from erosional events such as slumps and bank cuts. Flood hazards are primarily associated with the force of moving water to erode soils or damage or undercut structures that are close to the stream channels. The particular problem in this area is that additional development in areas of unstable soils or concentration of runoff from impervious areas routing may cause much higher peak flows with related stream erosion events.

The inter-butte landform area is characterized generally by low permeability soils on gently to moderately sloping terrain. Ecotrust (2000) mapped significant areas of hydric soils in this landform, indicating areas of periodic inundation. Shallow groundwater is reportedly in generally poor connectivity with the deeper Troutdale gravel aquifer and as a result, soils generally become saturated early in the rainfall season. Flood hazards in this area are largely associated with ponding and damage from inundation. There is some potential for damage from stream channel course changes during high water. Current flood hazard areas can generally be estimated by noting wetland (and former wetland) areas and areas that are within several feet (depending on the stream size) of the uppermost wetland area. Because flood hazards will depend on local gradients, channel conditions, soils, and development factors, hydraulic modeling is an appropriate tool for quantifying potential flood hazards in areas of concern.

The lower Clackamas River floodplain areas have defined flood hazards as noted on FEMA recurrence interval mappings of floodways and floodplain. Potential damage in this zone can come both from inundation and high velocity water damage.

Recommendations

- An inventory should be made of stream reaches that experienced significant erosion, mass wasting, or channel change events during the most recent (since 1990) extreme precipitation events. These areas should be considered for designation as flood erosion hazard areas pending area specific hydraulic analysis.
- Areas of steeper stream gradient and/or areas where previous large rain events (1996, 2004, 2006) have caused mass wasting, erosion, or channel changes should receive reach specific hydraulic/ hydrologic analysis prior to large scale developments.
- Areas with significant ponding during recent large rainfall events should be mapped, including both depth and duration of ponding. These areas should be considered for designation as flood hazard areas.
- Areas identified as potential flood hazard areas should receive additional evaluation of development elevations, proposed in-filling, and the routing/disposal of storm water prior to extensive development.

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